Tomato spotted wilt virus (TSWV): Update on biology and integrated management in the Central Valley of California

Robert L. Gilbertson
Department of Plant Pathology
University of California, Davis
A striking diversity of viruses have evolved to infect plants
Plant Viruses

- **Parasitic genetic elements** (RNA or DNA) covered by a protective protein shell

- Viruses take over the **cellular machinery** of the plant, spread throughout the infected plant, and cause disease symptoms

- **Plant-to-plant spread** of viruses most commonly occurs via **insects** (also via seed, nematodes, etc.)

- Plant viruses are very **difficult to diagnose and control**
**Tomato spotted wilt virus (TSWV): Monitoring and Management**
Tomato Spotted Wilt Disease

- Common disease of tomato in tropical and subtropical areas, such as Central America and Florida, but can also be a problem in areas with Mediterranean climates such as California.

- Caused by *Tomato spotted wilt virus* (TSWV).

- **Symptoms:** bronzing and necrosis of leaves and stems, chlorotic/yellow ringspots on fruits (can be confused with *Tobacco streak virus* and other viruses).

- Transmitted by various species of thrips, including the Western flower thrips (*Frankliniella occidentalis*).
Tomato spotted wilt symptoms in tomato in leaves include bronzing, wilting, and necrotic spots and veins.
Tomato fruit shows diagnostic ringspots on green and red fruits
### Crops/Ornamentals Susceptible to TSWV

<table>
<thead>
<tr>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans</td>
</tr>
<tr>
<td>Calendula</td>
</tr>
<tr>
<td>Celery</td>
</tr>
<tr>
<td>Cilantro/Coriander</td>
</tr>
<tr>
<td>Cole Crops</td>
</tr>
<tr>
<td>Dahlia</td>
</tr>
<tr>
<td>Eggplant</td>
</tr>
<tr>
<td>Gerbera</td>
</tr>
<tr>
<td>Gladiolus</td>
</tr>
<tr>
<td>Lettuce</td>
</tr>
<tr>
<td>Nasturtium</td>
</tr>
<tr>
<td>Oregano</td>
</tr>
<tr>
<td>Peas</td>
</tr>
<tr>
<td>Pepper</td>
</tr>
<tr>
<td>Petunia</td>
</tr>
<tr>
<td>Sages</td>
</tr>
<tr>
<td>Spinach</td>
</tr>
<tr>
<td>Sunflower</td>
</tr>
<tr>
<td>Tomato</td>
</tr>
</tbody>
</table>

### Weeds susceptible To TSWV

<table>
<thead>
<tr>
<th>Weed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bind weed</td>
</tr>
<tr>
<td>Black nightshade</td>
</tr>
<tr>
<td>Burr Clover</td>
</tr>
<tr>
<td>Chickweed</td>
</tr>
<tr>
<td>Cocklebur</td>
</tr>
<tr>
<td>Hairy Fleabane</td>
</tr>
<tr>
<td>Lambs Quarters</td>
</tr>
<tr>
<td>Malva</td>
</tr>
<tr>
<td>Miners Lettuce</td>
</tr>
<tr>
<td>Nettleleaf Goosefoot</td>
</tr>
<tr>
<td>Purslane</td>
</tr>
<tr>
<td>Redroot Pigweed</td>
</tr>
<tr>
<td>Shepherd’s Purse</td>
</tr>
<tr>
<td>Slender Pigweed</td>
</tr>
<tr>
<td>Sow Thistle</td>
</tr>
<tr>
<td>Swine Cress</td>
</tr>
<tr>
<td>Yellow Sweet Clover</td>
</tr>
</tbody>
</table>

Richard Smith, Vegetable Crop and Weed Science Farm Advisor, Monterey County
Tospovirus Transmission Cycle

Egg

1st instar

2nd instar

Pupal Stages Do Not Feed

Virus Passage

Only adults that acquire as larvae can transmit.

Photos by J.K. Clark
CTRI Project objectives

- Develop an understanding of when and where TSWV gains entry into California processing tomatoes
  - Monitor thrips populations and virus incidence on transplants and in transplanted and direct-seeded fields

- Identify potential inoculum sources
  - Crop plants, weeds, ornamentals
  - Focus on areas having outbreaks

- Assess various thrips control strategies

- Develop a regional integrated management program
Monitoring tomato transplants

- **Transplant greenhouses**
  - Greenhouse operations monitored for thrips and TSWV
  - Yellow sticky cards for monitoring thrips
  - Indicator plants and visual inspection for TSWV

- **Results:** Relatively low thrips populations (especially in closed greenhouses) and no evidence of TSWV infection of transplants
Thrips monitoring in tomato transplants - Results

Average thrips caught on yellow sticky cards. Monthly counts represent 4 weekly sampling dates. CA Transplant greenhouses were closed houses. Thrips populations outside greenhouses were monitored for CA Transplants only.

Transplant Houses 2007

Transplant Houses 2008
Fava beans and Petunia plants show TSW-symptoms more rapidly than tomatoes

TSWV was not detected on indicator plants or in tomato transplants in any of the monitored greenhouses
Monitoring of transplants

- Relatively low thrips populations (especially in closed greenhouses) on transplants
- Overall thrips populations were higher (four-fold) in 2008 compared with 2007
- No evidence of TSWV infection of transplants
- Transplants are not a major source of thrips or TSWV for processing tomatoes
Monitoring thrips and TSWV in tomato fields

- Direct-seeded and transplanted tomato fields
- Thrips are monitored with yellow sticky cards and flower counts from 5 locations within each field
- Virus incidence determined from randomly selected rows (total 50 yards/location for 5 locations/field)
- TSWV infection confirmed in selected plants with immunostrips
<table>
<thead>
<tr>
<th>Fresno &amp; Kings Counties</th>
<th>Locations</th>
<th>Merced County</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harris Almond</td>
<td>Coalinga</td>
<td>LG1 Winter Rad</td>
<td>Le Grand Ranch</td>
</tr>
<tr>
<td>Sano Almond</td>
<td>Firebaugh</td>
<td>LG2 Winter Rad</td>
<td>Le Grand Ranch</td>
</tr>
<tr>
<td>Almond 1,2 and 3</td>
<td>S Huron</td>
<td>CD1 Winter Rad</td>
<td>Childs Ave</td>
</tr>
<tr>
<td>Hammik-TP</td>
<td>Firebaugh</td>
<td>CD2 Winter Rad</td>
<td>Childs Ave</td>
</tr>
<tr>
<td>5 Star-TP</td>
<td>Five Points</td>
<td>CW1 Winter Rad</td>
<td>Chowchilla</td>
</tr>
<tr>
<td>5 Star-DS</td>
<td>Five Points</td>
<td>AT1 Winter Rad</td>
<td>Athlone / S Mush Rd</td>
</tr>
<tr>
<td>Sano-TP</td>
<td>Firebaugh</td>
<td>LG3 Spring Rad</td>
<td>Le Grand Ranch</td>
</tr>
<tr>
<td>Harris Organic Fresh Market</td>
<td>Coalinga</td>
<td>CD3 Fresh Market-TP</td>
<td>Childs Ave/ Arboleda</td>
</tr>
<tr>
<td>Westside (30th Ave)-TP</td>
<td>West Side</td>
<td>CD4 Fresh Market-TP-L</td>
<td>Childs Ave</td>
</tr>
<tr>
<td>Woolf Las/Trac-TP</td>
<td>S Huron</td>
<td>LG4 Processing-TP</td>
<td>Le Grand Rd</td>
</tr>
<tr>
<td>Woolf Creek 1-DS</td>
<td>W Huron</td>
<td>LG5 Fresh Market-TP-L</td>
<td>Le Grand Rd</td>
</tr>
<tr>
<td>Woolf Creek 2-TP</td>
<td>W Huron</td>
<td>MN1 Processing-TP</td>
<td>Minturn / B. Hollow</td>
</tr>
<tr>
<td>Jones-DS</td>
<td>NE Kettleman City</td>
<td>MN2 Fresh Market-TP-L</td>
<td>Minturn Rd</td>
</tr>
<tr>
<td>Jones-TP</td>
<td>NE Kettleman City</td>
<td>GT1 Processing-TP</td>
<td>Gillette / Burchell</td>
</tr>
<tr>
<td>Huron Rad</td>
<td>S Huron</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TP, transplanted processing tomato; DS, direct seeded processing tomato; Rad, radicchio; L, late planted
Thrips monitoring: yellow sticky cards

**Fresno & Kings Counties 2007**

<table>
<thead>
<tr>
<th>Date</th>
<th>Jones TP</th>
<th>Jones B Pepper</th>
<th>Woolf DS</th>
<th>Woolf T Tomato</th>
<th>FS D Tom</th>
<th>FS T Tom</th>
<th>Lassen&amp;Jayne</th>
<th>Jayne&amp;Aqueduct</th>
<th>Radicchio</th>
</tr>
</thead>
</table>

**Fresno & Kings Counties 2008**

<table>
<thead>
<tr>
<th>Date</th>
<th>Harris Almond</th>
<th>Sano Almond</th>
<th>5 Stars DS</th>
<th>Hammik TP</th>
<th>5 Star TP</th>
<th>Sano TP</th>
<th>Harris O.Fre. To</th>
<th>Wside TP(30th Ave)</th>
<th>Woolf Las/Trac TP</th>
<th>Woolf Creek 1 DS</th>
<th>Woolf Creek 2 TP</th>
<th>Jones DS</th>
<th>Jones TP</th>
<th>Huron Rad</th>
</tr>
</thead>
</table>

**Thrips Number**

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000
Thrips monitoring: yellow sticky cards

Merced County 2008

Date

Thrips Number

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct

LG3 Rad
CD2 Rad
CD3 TP
CD4 TP
LG4 TP
MN1 TP
GT1 TP
Thrips monitoring in flowers

Average Thrips Per Flower
2007

Average Thrips Per Flower
2008
Results-Thrips populations

• Thrips populations **begin to increase in March/April; peaked from May-July; and slowly declined until late fall (October) to winter when populations are lowest**

• In **2007, populations were moderate, whereas in 2008 populations were twice to four-fold as high**

• Detection of larvae in tomato flowers indicates **thrips reproduction on tomato**

• All were identified as **western flower thrips**
TSWV Incidence (%) 2007 and 2008

Most fields remained less than 5%
Results-TSWV incidence

• In 2007, TSWV was **first detected 20 April** in a direct seeded field, whereas in 2008, TSWV **first appeared mid-May**

• In 2007, spotted wilt appeared in most fields but late and at low incidences (>1%-3%)

• In 2008, **overall TSWV pressure was greater**, especially in later planted fields (incidences ranged from 0%-15%), and ID was complicated by higher incidences of curly top virus

• TSWV incidence was **slightly greater in direct-seeded versus transplanted fields**

• In 2007 and 2008 overall **economic losses due to TSWV in monitored fields** was minimal
Monitoring tomato fields-Grower alerts

- Growers were **promptly advised on the detection of thrips and TSWV in tomato crops via CTRI in 2007 and 2008**
- This allowed for **implementation of thrips management strategies** (primarily chemical control), which is thought to slow the spread of virus (possibly by reducing the number of virus-carrying adults) and the build-up of thrips populations
**TSWV-Inoculum Sources**

- **Winter surveys** of areas with high TSWV to look for **reservoir hosts**, including weeds, winter crops and perennials (almonds)
- **Monitored** **spring lettuce crops** for spotted wilt
- **Focus on the potential of radicchio to serve as a bridge crop between tomato crops**
Other sources examined in 2008

Almonds
- thrips populations were low in almond orchards (yellow sticky cards) and in flowers
- TSWV not detected in thrips from almond (almond is not a reported host for TSWV)

Weeds
- a variety of common weeds were collected throughout the growing season and in areas known to have TSWV outbreaks
- most samples were negative for TSWV, with an incidence of <0.1%
- weeds that were positive included groundsel, London rocket, malva, prickly lettuce, sowthistle
# Weed survey results for TSWV incidence (Fresno and Merced counties)

<table>
<thead>
<tr>
<th>Weed</th>
<th>Tested (+)</th>
<th>Weed</th>
<th>Tested (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnyard grass</td>
<td>25 (0)</td>
<td>Lambs quarters</td>
<td>63 (0)</td>
</tr>
<tr>
<td>Black nightshade</td>
<td>25 (0)</td>
<td>Malva</td>
<td>110 (1)</td>
</tr>
<tr>
<td>Bindweed</td>
<td>25 (0)</td>
<td>Mustard</td>
<td>60 (0)</td>
</tr>
<tr>
<td>Bur clover</td>
<td>25 (0)</td>
<td>Nettle</td>
<td>25 (0)</td>
</tr>
<tr>
<td>Common sunflower</td>
<td>25 (0)</td>
<td>Pigweed</td>
<td>25 (0)</td>
</tr>
<tr>
<td>Dodder</td>
<td>25 (0)</td>
<td>Prickly lettuce</td>
<td>90 (2)</td>
</tr>
<tr>
<td>Fiddle neck</td>
<td>25 (0)</td>
<td>Purslane</td>
<td>25 (0)</td>
</tr>
<tr>
<td>Ground cherry</td>
<td>25 (0)</td>
<td>Russian thistle</td>
<td>25 (0)</td>
</tr>
<tr>
<td><strong>Groundsel</strong></td>
<td><strong>40 (1)</strong></td>
<td><strong>Sowthistle</strong></td>
<td><strong>60 (1)</strong></td>
</tr>
<tr>
<td>Jimsonweed</td>
<td>25 (0)</td>
<td>Tree tobacco</td>
<td>25 (0)</td>
</tr>
</tbody>
</table>

(+) number of plants tested positive for TSWV by immunostrips and/or PCR
TSWV in Lettuce

Detected in Fresno in spring lettuce in 2007 and 2008, but was sporadic and no economic losses.
Radicchio - a reservoir crop for TSWV

Average Thrips Number per Card

Radicchio ‘07

March April
TSWV in Peppers

-a highly susceptible host that can amplify thrips and TSWV
Detection of TSWV in thrips

- An test (the RT-PCR test) has been developed that allows for detection of TSWV in thrips
- Can detect TSWV in thrips from sticky cards or plants
- Can detect TSWV in a single insect
The RT-PCR test allows for detection of TSWV in thrips

- This will help determine **when virus-carrying thrips are present**
- Could be used to help determine if **viruliferous thrips overwinter** and can be inoculum sources early in the growing season
We can detect the presence of TSWV in thrips by RT-PCR

- Preliminary results indicate that early in the season many thrips are not carrying the virus
- Consistent with the thrips picking up virus from crop plants infected early in the season (from thrips from weed, ornamental or bridge hosts)
- By mid-season (July) TSWV is being detected in more thrips samples
- Consistent with early efforts to suppress thrips populations
Chemical Control of Thrips

• It is important that thrips management be implemented prior to or immediately following initial TSWV findings
• Critical to reduce the number of virus-carrying adults by controlling larvae early in the season
• Thrips insecticide trials have been conducted at Westside
• Based on 2007 and 2008 trials the best materials were: Dimethoate, Lannate, Radiant, and Mustang+Beleaf
• However, the effect was not long-lasting (7-10 days)
• Neonicotinoids (e.g., imidicloprid, thiamethoxam) are not effective
Biology of thrips/TSWV in the Central Valley

- Low populations of thrips persist overwinter and in association with weeds and winter (bridge) crops.
- TSWV does not seem to overwinter well in weeds or other winter crops (almonds, onion and wheat), but it can be present in bridge crops such as lettuce and radicchio.
- During the growing season, TSWV builds-up in susceptible crops, mostly tomato and peppers; thrips increase on many hosts, including alfalfa, onion, wheat.
- Thus, it is important that thrips management be implemented prior to or immediately following initial TSWV findings to minimize disease pressure, especially on late-planted crops.
- Critical to reduce the number of virus-carrying adults by controlling larvae early in the season.
Integrated TSWV Management

• **Before planting**
  - Variety selection (TSWV resistant [Sw-5] varieties)
  - Virus-free transplants
  - Avoid ‘hot spots’ or fields known to have TSWV

• **During the season**
  - Monitoring for thrips/TSWV
  - Thrips management early (to manage larval populations)/rotate classes of materials used
  - Use of plant defense activators (Actigard)?
  - Reflective mulches, roguing (?)

• **After harvest**
  - Prompt sanitation
  - Avoid ‘bridge’ crops that carry the TSWV and overlap with tomato/pepper (e.g., radicchio)
  - Reservoir (weed host) management
  - This should be done on a regional basis
Why the increase in thrips and tospoviruses in California?
New tospoviruses are appearing in California crops

*Impatiens necrotic spot virus* (INSV) in lettuce in Monterey County

*Iris yellow spot virus* (IYSV) in many onion-growing areas
Appearance of a new tomato-infecting virus in 2008
Appearance of a new tomato-infecting virus in 2008

- Appears to be a new ilarvirus
- Most similar to *Parietaria mottle virus*, an ilarvirus that causes leaf and stem necrosis in Europe and *Tobacco streak virus* (TSV)
- TSV transmission occurs when infected pollen is introduced in leaves by wounds made by thrips feeding
- Name *Tomato necrotic spot virus* proposed
Acknowledgements

UC Davis
- Diane Ullman
- Ozgur Batuman
- Sarah Dalmacio, Rachel Heinz

UCCE
- Michelle LeStrange
- Scott Stoddard
- Tom Turini

CTRI

Transplant producers, tomato growers, and PCAs